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Various remote sensing equations dealing with ocean color models (R. W. Austin, in Optical Aspects of Oceanography, eds. Jerlov and Nielsen, Academic Press., London, 1974) active and passive hydrographic surveying (G. C. Guenther, NOAA Professional Papers, NOS-1, 1985) include the bottom reflectance as a significant variable. Bottom spectral reflectance quantifies the effect the optical characteristics of the bottom sediments have on the upwelling light field. In optically shallow waters which possess a large bottom component in the upwelling light field, light reflected from the bottom can be backscattered into the uplooking irradiance stream and influence the spectral content of the measured downwelling signal. The extent to which this occurs is important to quantify simply because the measurement of water reflectances are biased by this process. Thus, any computations which are based upon these measurements are to some degree suspect. The objective of this work is to model the contamination of the downwelling stream due to the backscatter of the bottom upwelling light field. Then the model will be used to determine the extent of 'contamination' using collected field data.

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BACKSCATTER OF BOTTOM REFLECTED LIGHT INTO THE DOWNWELLING LIGHT STREAM

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SUMMARY

Various remote sensing equations dealing with ocean color models (R.W. Austin, in Optical Aspects of Oceanography, eds. Jerlov and Nielsen, Academic Press., London, 1974) active and passive hydrographic surveying (G.C. Guenther, NOAA Professional Papers, NOS-1, 1985) include the bottom reflectance as a significant variable. Bottom spectral reflectance quantifies the effect the optical characteristics of the bottom sediments have on the upwelling light field. In optically shallow waters which possess a large bottom component in the upwelling light field, light reflected from the bottom can be backscattered into the uplooking irradiance stream and influence the spectral content of the measured downwelling signal. The extent to which this occurs is important to quantify simply because the measurement of water reflectances are biased by this process. Thus, any computations which are based upon these measurements are to some degree suspect. The objective of this work is to model the contamination of the downwelling stream due to the backscatter of the bottom upwelling light field. Then the model will be used to determine the extent of 'contamination' using collected field data.

The modeling approach used is analogous to the Single-Scattering Irradiance (SSI) model. (W.D. Philpot, App. Opt., 26, 4123-4132, 1987). The present model is essentially an 'inverted' SSI model wherein the source of light is the bottom rather than the surface. The model assumes optically shallow, stratified waters. The backscatter seen at z, the scattering layer, in the downwelling direction is

$$dE_{dw}(z) = E_u(d)\, B_{ss} \exp\left[-\int_z^d k_u\, dz''\right] \qquad (1)$$

where k_u is the upwelling irradiance attenuation coefficient, B_{ss} is the single scattering coefficient defined by the equation
and E_u is the upwelling irradiance field. The change in the downwelling irradiance at depth z' due to the backscatter at depth z is given by

$$B_{ss}=\frac{dE_{bd}(z)}{E_u(z)\,dz} \tag{2}$$

$$dE_{bd}(z') = E_u(d+)\,B_{ss}\exp\left(-\int_z^{d+} k_u dz''\right)\exp\left(-\int_z^{z'} aD_d dz''\right)dz \tag{3}$$

where k_u is the upwelling diffuse attenuation coefficient, a is the absorption coefficient, and D_d is the downwelling distribution factor defined by

$$D_d(z) = \frac{E_{od}(z)}{E_d(z)} \tag{4}$$

where E_{od} is the downwelling scalar irradiance. Integrating from z' to the surface, we obtain an expression for the contribution to the downwelling irradiance at depth z' due to backscatter from layers of water between depths z' and the surface. The expression is

$$E_{bd}(z') = E_u(z')\int_0^{z'} B_{ss}(z)\exp\left[-\int_z^{z'} k_u dz''\right]\exp\left[-\int_z^{z'} a(z'')\,D_d(z'')\right. \tag{5}$$

where $E_u(z')$ is given by

$$E_u(z') = E_u(d)\exp\left[-\int_{z'}^{d} k_u(z'')\,dz''\right] \tag{6}$$

which is the attenuation suffered by the upwelling light field in transit from the bottom to z' -- where the measurement is to be made.

The model is used with a combined field data set and shows that the contamination, or error, in the downwelling spectrum measured in similar optically shallow sites with a relatively low bottom reflectance ranges from about 0.7% to 1.6% depending on wavelength and proximity to the bottom. It is shown that should the bottom reflectance increase, then there is a corresponding increase in the contamination seen in the downwelling stream. For a 25% bottom reflectance, the contamination ranged from about 0.2% to 6%, again depending on wavelength and depth. Since bottom reflectance values from some areas could exceed 35% reflectivity in some wavebands, it is conceivable that contamination percentages could approach 10%. Furthermore, it has been shown that should a decrease in water clarity, or an increase in water attenuation, occur, then the contamination seen tends to be diminished.